Fraunhofer Lighthouse Project NeurOSmart

Analog neuromorphic accelerators enabling efficient and smart sensors

Motivation

Tomorrow's factory and logistics environments are dynamic and characterized by robots working alongside humans sharing the same space. As the next generation of robotic systems will become more autonomous, the number of sensors, the efforts required to link their data, and the computational power required to enable reliable and safe real-time operation are skyrocketing.
As a result, sensor systems and their data processing are moving towards decentralized hierarchies and take inspiration of highly efficient biological counterparts, i.e. the human brain. In practice this approach requires a combination of hardware and software components specifically designed for each other to leverage its full potential. A newly designed, energy efficient analog neuromorphic accelerator will offer a high-performance alternative to intelligent data processing, as it enables asynchronous, event-based, and highly parallel computations.

Outcome

The NeurOSmart project aim is to develop a high-performance LiDAR sensor system with a directly integrated digital AI-based preprocessing pipeline and a dedicated analog, neuromorphic, ultra-low-power in-memory accelerator. Thus, embedding decentralized and highly efficient data processing capabilities into the sensor system. This will significantly reduce the computational load on the subsequent decision deriving HPC systems while simplifying the integration of multiple sensor systems, independently of their measurement principle and data streams. Hence, the energy consumption of the data processing is reduced by two orders of magnitude compared to current state of the art solutions. The result is a novel, neuromorphic approach to efficient smart sensor for mobile and autonomous systems. Initial system components are available in the upcoming months, complete demonstrators are released in 2025.

Project details

- Duration: 4 years (Jan. 2022 - Dec. 2025)
- Fraunhofer project partners: **ISIT, IPMS, IMS, IWU, IAIS**
- Benefits: Energy efficient, AI-based processing in sensor integrated, neuromorphic, safety systems compatible

Interested in being a part of our journey or utilize our technologies in your sensor systems and applications?

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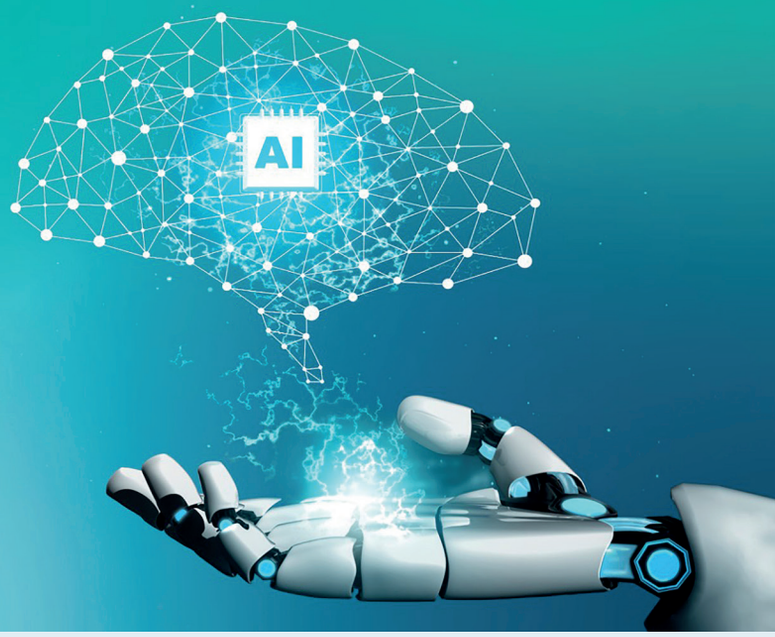
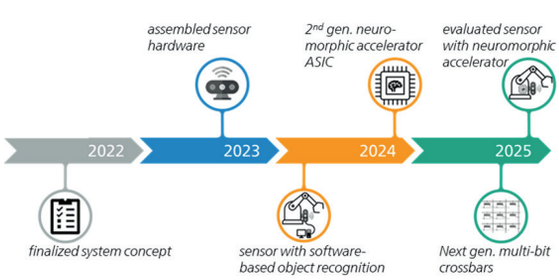


What's inside?

As an initial demonstrator for the integration into a competitive sensor system, NeurOSmart uses an open, Fraunhofer-developed, MEMS-scanner-based sequential flash LiDAR system as the sensor base to provide direct access to the incoming data streams. In addition, a highly scalable, neuromorphic HPC chip is coupled with a sophisticated, AI-supported preprocessing pipeline to interpret the data directly at the sensor. This eliminates the need for elaborate communications and edge compute infrastructures, reducing opportunities to attack the system. The processor cores for preprocessing and accelerator memory management are implemented based on RISC-V architecture. The accelerator ASIC itself consists of HfO_2-based FeFET crossbars, which are particularly energy efficient compared to alternative approaches. In addition, the new ferroelectric material AlScN is being validated for its use as a multibit memory cell in future, even higher-performance accelerator chips.

System specifications & deployment scenario

A smart sensor with a field range of up to 12 m, detecting and classifying objects on the basis of individual pixels in a field of view of 90° x 90° at 112x112 pixels, will be developed. Operating in real time with frame rates > 20 Hz and power consumption of a few 10 W. Initially, the NeurOSmart smart sensor will be benchmarked against functional safety systems for collaborative robots. In the future it will be evaluated in mobile applications for AMRs and AGVs before incorporating different sensor types.



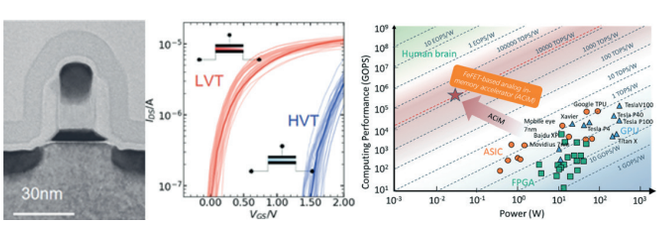
Project timeline with milestones.

Technology involved

LiDAR	MEMS-scanner-based sequential flash
Preprocessing	Highly scalable and flexible digital preprocessing onboard (RISC-V based with application specific cores)
AIRISC	RISC-V processor for smart sensors and embedded AI applications
AIfES	Open source platform-independent AI library for embedded system
Accelerator	Analog in-memory compute ASIC based on HfO_2 FeFET crossbars
Outlook	Multibit-memory cells based on AlScN FeFETs

The open-source components AIfES and AiRISC are available at: www.aifes.de & www.airisc.de

NeurOSmart scientists gathering training data on current sensor hardware (left) and 3D modeled digital twin with simulated sensor depth data as well as annotated objects (right).



Accelerator memory element that can store and process data at the same time, yielding to energy efficiencies >10000 TOPS/W.